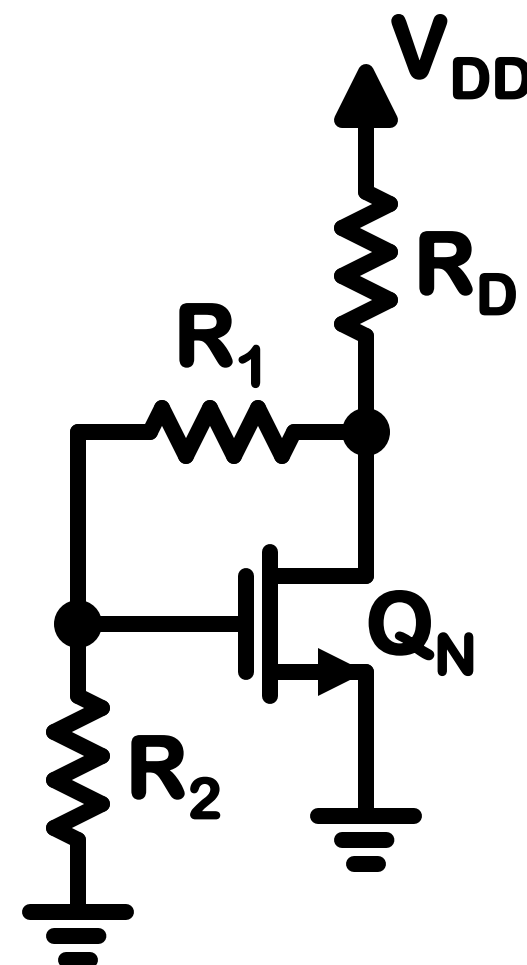
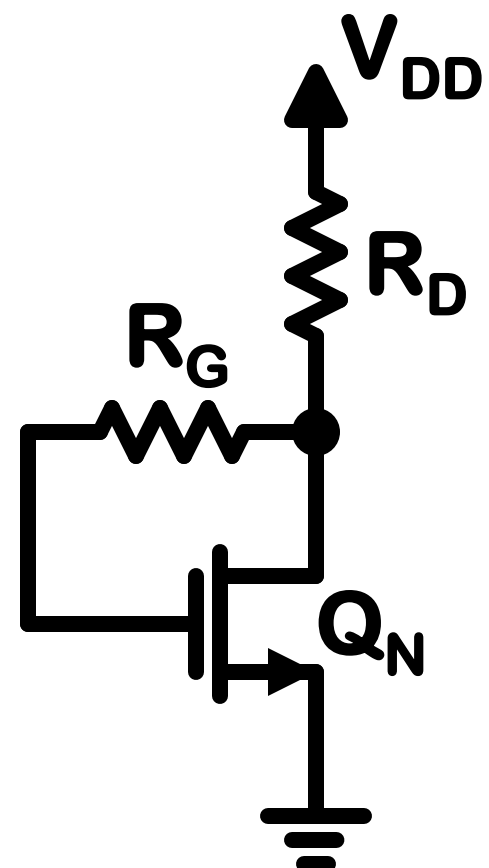
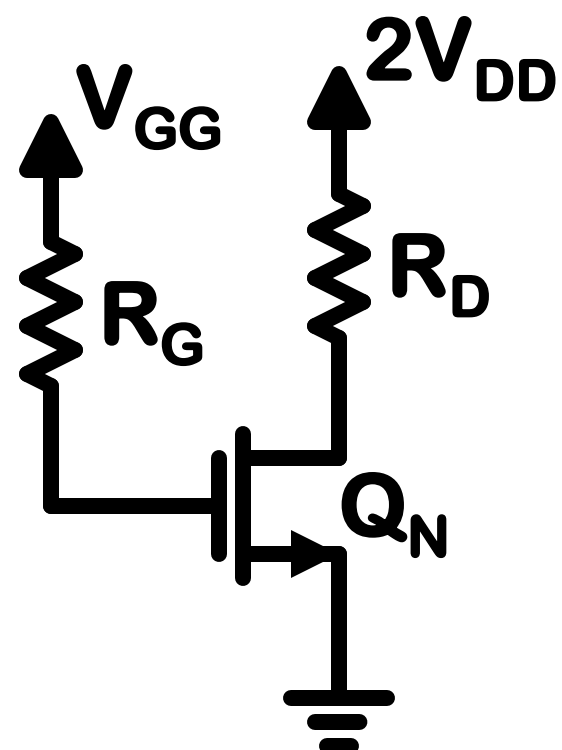
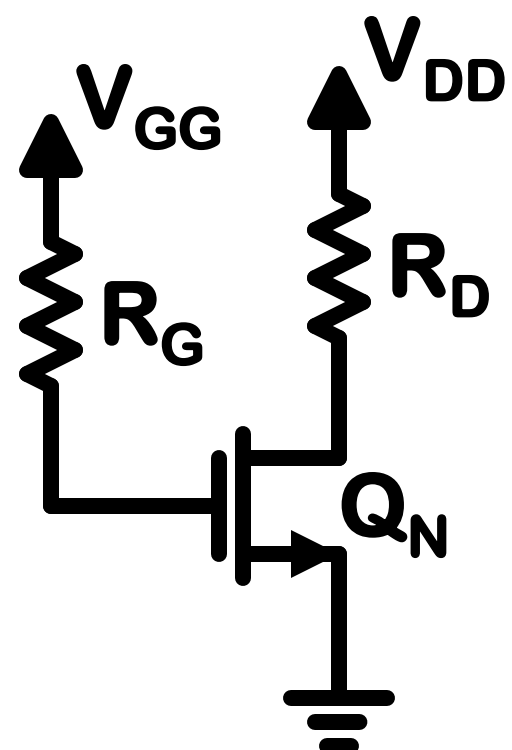
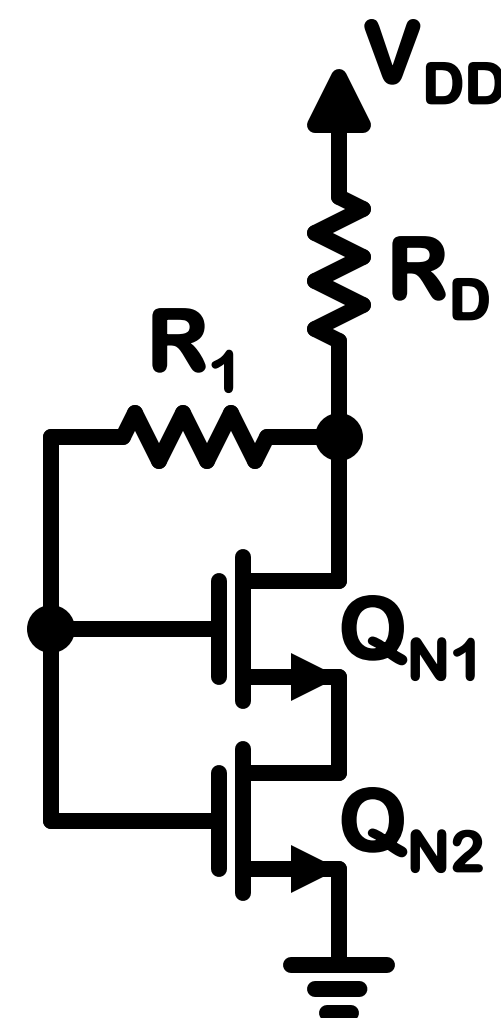
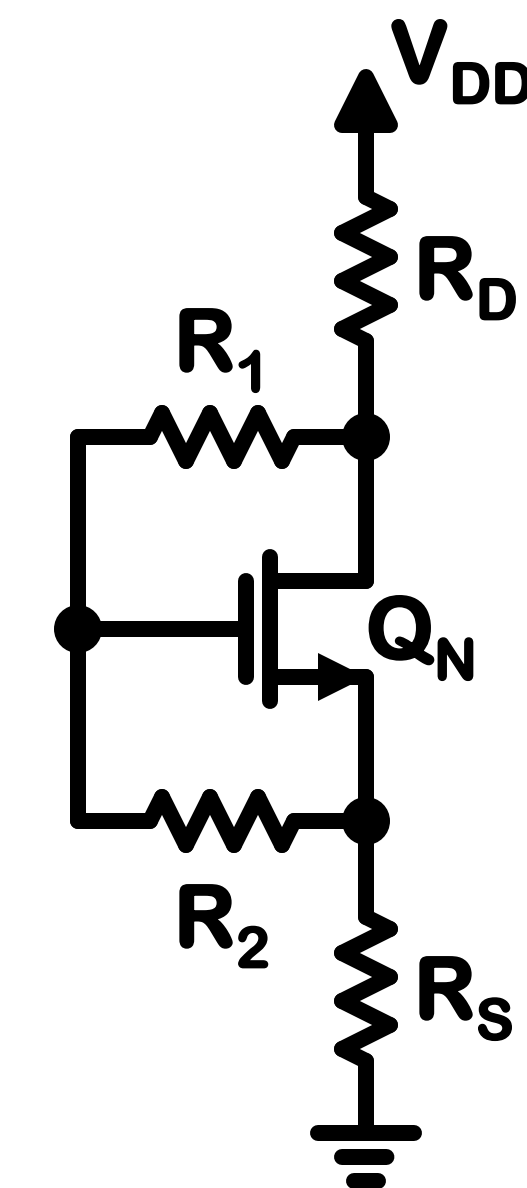
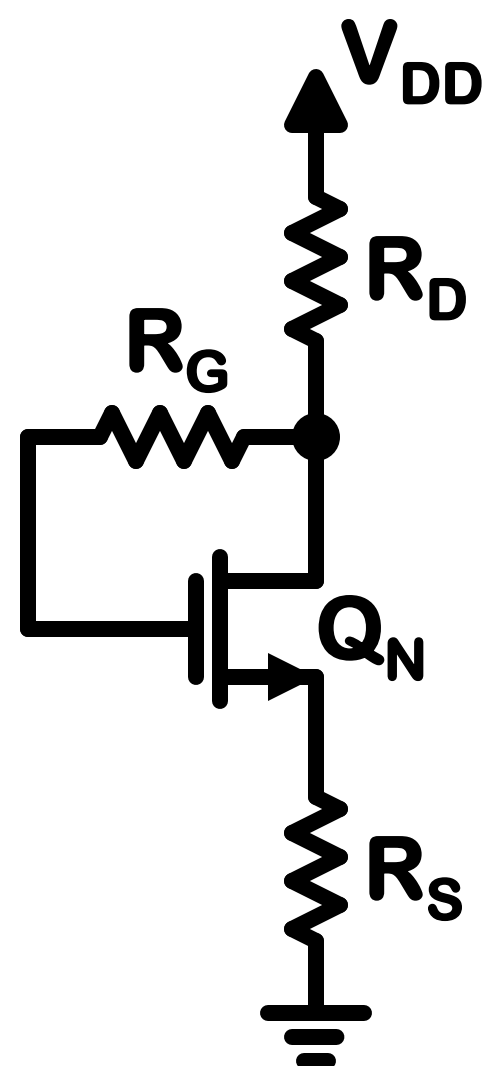
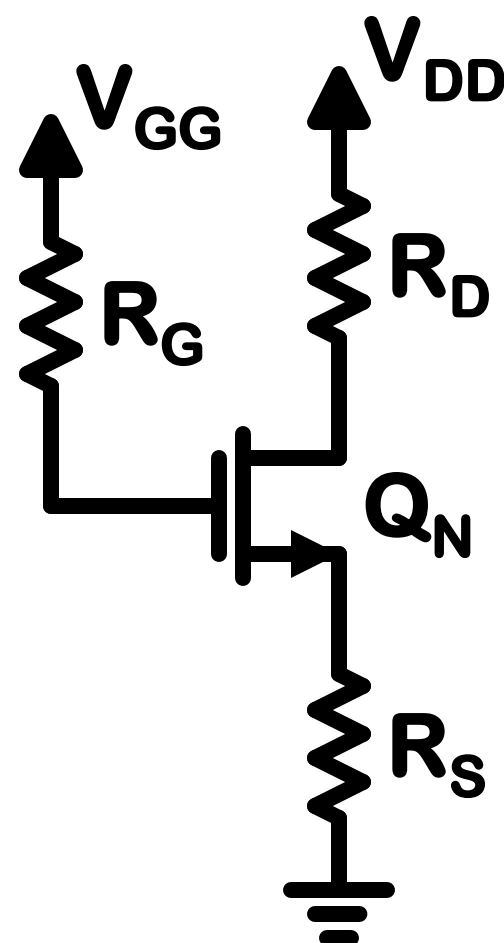
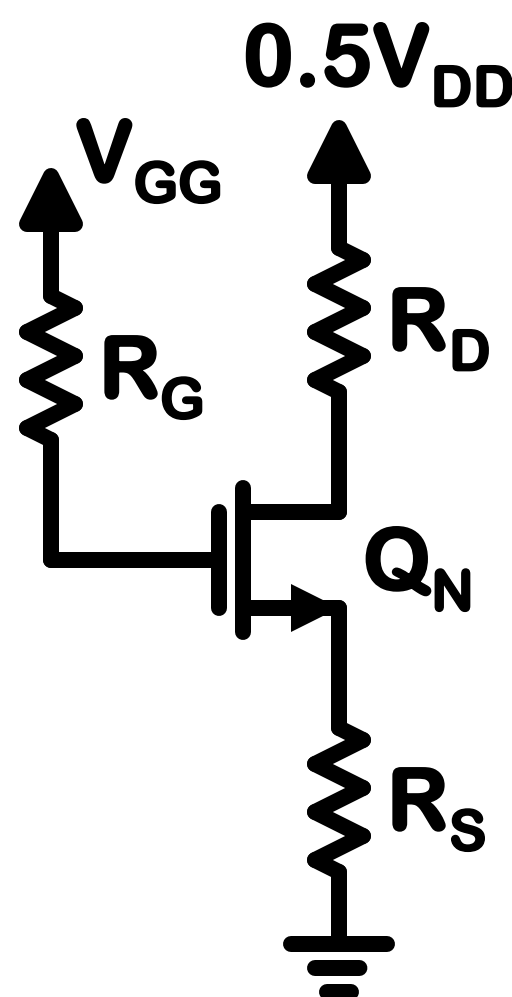
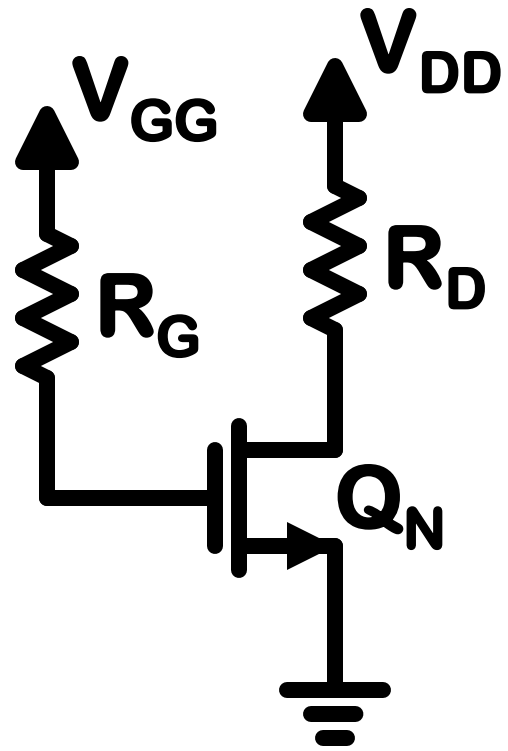




$V_{DD} = 6V$
 $V_{GG} = 4V$
 $R_G = 10k\Omega$
 $R_D = 500\Omega$
 $R_S = 200\Omega$
 $R_1 = 200\Omega$
 $R_2 = 300\Omega$
 $k_n = 2 \text{ mA/V}^2$
 $V_{tn} = 1V$





$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Triode

2. Enforce (device equation)

$$i_D = 0.002(v_{GS} - V_{tn} - v_{DS}/2)v_{DS}$$

3. Solve

a. Circuit Equations

$$v_{GS} = 4V$$

$$i_D = (6 - v_{DS})/500$$

b. Solve

$$(6 - v_{DS})/500 = 0.002(4 - 1 - v_{DS}/2)v_{DS}$$

$$6 - v_{DS} = 3v_{DS} - 0.5v_{DS}^2$$

$$0.5v_{DS}^2 - 4v_{DS} + 6 = 0$$

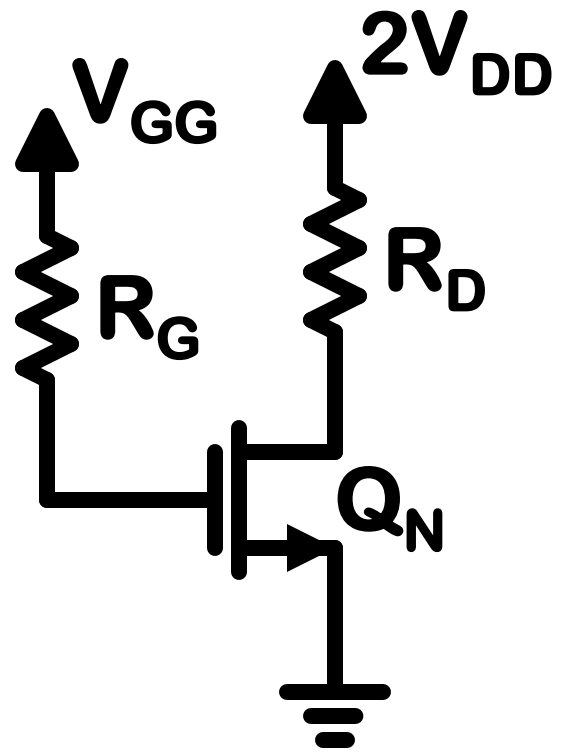
$$v_{DS} = 4 \pm \sqrt{16 - 12} = 6V \text{ or } 2V \dots \text{Choose } 2V$$

$$i_D = (6 - 2)/500 = 4/500 = 8 \text{ mA}$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} < v_{GS} - V_{tn}, \text{ Yes}$$



$$V_{DD} = 6V$$

$$V_{GG} = 4V$$

$$R_G = 10k\Omega$$

$$R_D = 500\Omega$$

$$R_S = 200\Omega$$

$$R_1 = 200\Omega$$

$$R_2 = 300\Omega$$

$$k_n = 2 \text{ mA/V}^2$$

$$V_{tn} = 1V$$

1. Saturation

2. Enforce (device equation)

$$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$$

3. Solve

a. Circuit Equations

$$v_{GS} = 4V$$

$$i_D = .001(4-1)^2 = 9 \text{ mA}$$

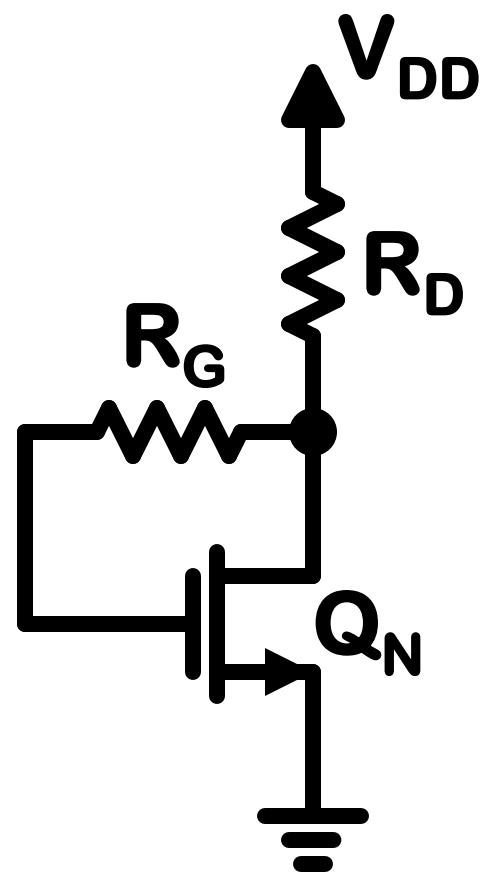
b. Solve

$$v_{DS} = 12 - 500(0.009) = 7.5V$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$



$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Saturation

2. Enforce (device equation)

$$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$$

3. Solve

a. Circuit Equations

$$v_{GS} = v_{DS}$$

$$i_D = (6 - v_{GS})/500$$

b. Solve

$$(6 - v_{GS})/500 = 0.001(v_{GS} - 1)^2$$

$$12 - 2v_{GS} = v_{GS}^2 - 2v_{GS} + 1$$

$$v_{GS}^2 - 11 = 0$$

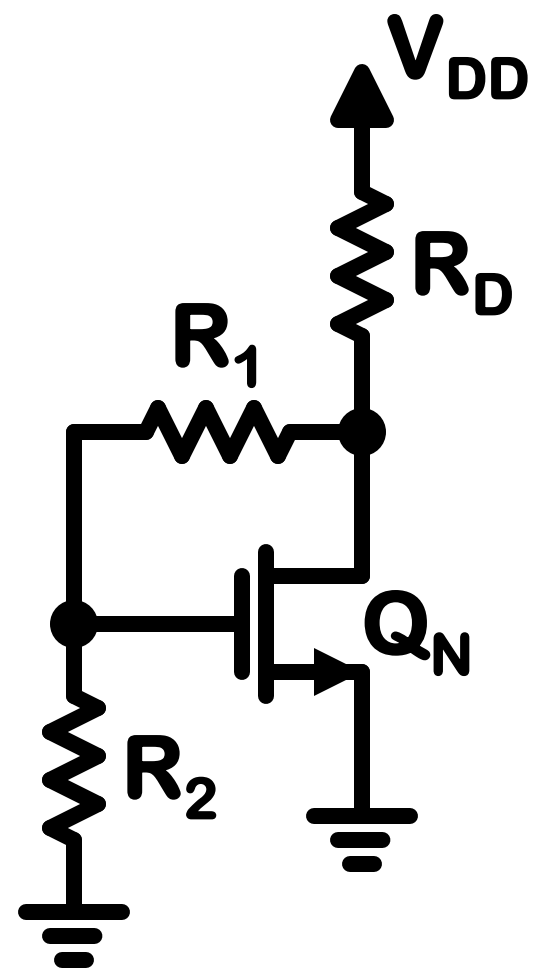
$$v_{GS} = \pm \sqrt{11} = \pm 3.32V \dots \text{choose } 3.32V$$

$$i_D = 5.37 \text{ mA}$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$



$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Saturation

2. Enforce (device equation)

$$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$$

3. Solve

a. Circuit Equations

$$v_{GS} = 3v_{DS}/5 \text{ or } v_{DS} = (5/3)v_{GS}$$

$$i_{RD} = i_D + i_{R1}$$

$$i_{RD} = (6 - (5/3)v_{GS})/500$$

$$i_{R1} = (5/3)v_{GS}/500$$

b. Solve

$$(6 - (5/3)v_{GS})/500 - (5/3)v_{GS}/500 = 0.001(v_{GS} - 1)^2$$

$$12 - (20/3)v_{GS} = v_{GS}^2 - (6/3)v_{GS} + 1$$

$$v_{GS}^2 + (14/3)v_{GS} - 11 = 0$$

$$v_{GS} = (-14/3 \pm \sqrt{(14/3)^2 + 44})/2 = \text{choose } 1.72V$$

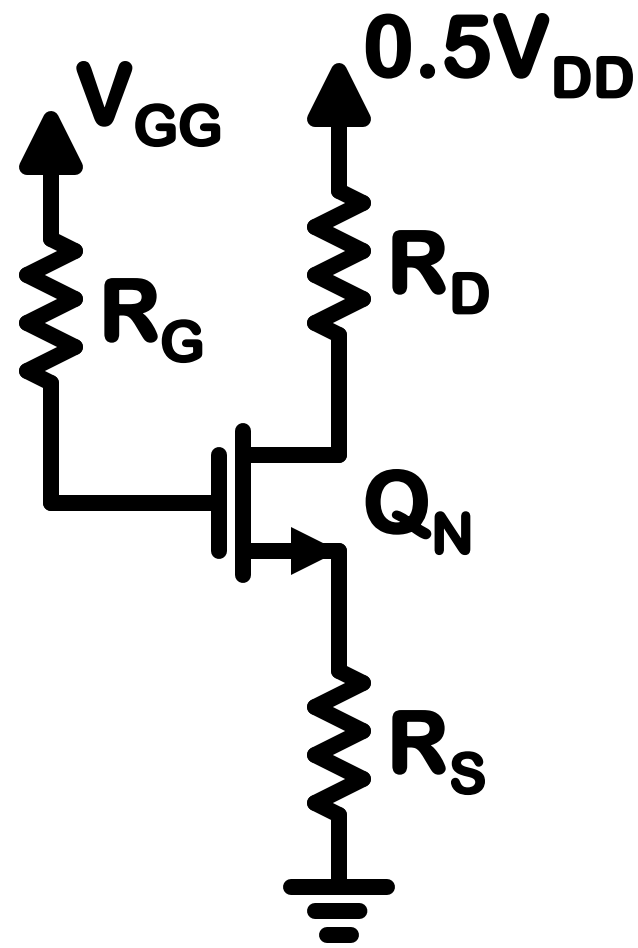
$$v_{DS} = 2.87V$$

$$i_D = 0.518 \text{ mA}$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$



$$V_{DD} = 6V$$

$$V_{GG} = 4V$$

$$R_G = 10k\Omega$$

$$R_D = 500\Omega$$

$$R_S = 200\Omega$$

$$R_1 = 200\Omega$$

$$R_2 = 300\Omega$$

$$k_n = 2 \text{ mA/V}^2$$

$$V_{tn} = 1V$$

1. Triode

2. Enforce (device equation)

$$i_D = 0.002(v_{GS} - V_{tn} - v_{DS}/2)v_{DS}$$

3. Solve

a. Circuit Equations

$$v_{GS} = 4 - 200i_D \text{ or } i_D = (4 - v_{GS})/200$$

$$i_D = (3 - v_{DS})/700$$

b. Solve

$$(3 - v_{DS})/700 = (4 - v_{GS})/200$$

$$6 - 2v_{DS} = 28 - 7v_{GS} \text{ or } v_{GS} = (2v_{DS} + 22)/7$$

$$(3 - v_{DS})/700 = 0.002((2v_{DS} + 22)/7 - 1 - v_{DS}/2)v_{DS}$$

$$3 - v_{DS} = 1.4((2v_{DS} + 22)/7 - 1 - v_{DS}/2)v_{DS}$$

$$3 - v_{DS} = (.2(2v_{DS} + 22) - 1.4 - .7v_{DS})v_{DS}$$

$$3 - v_{DS} = (.4v_{DS} + 4.4) - 1.4 - .7v_{DS})v_{DS}$$

$$3 - v_{DS} = 3v_{DS} - .3v_{DS}^2$$

$$0.3v_{DS}^2 - 4v_{DS} + 3 = 0$$

$$v_{DS} = (4 \pm \sqrt{16 - 4 \cdot 0.3 \cdot 3})/.6 = 0.8V \text{ or } 12.5V$$

Choose 0.8V

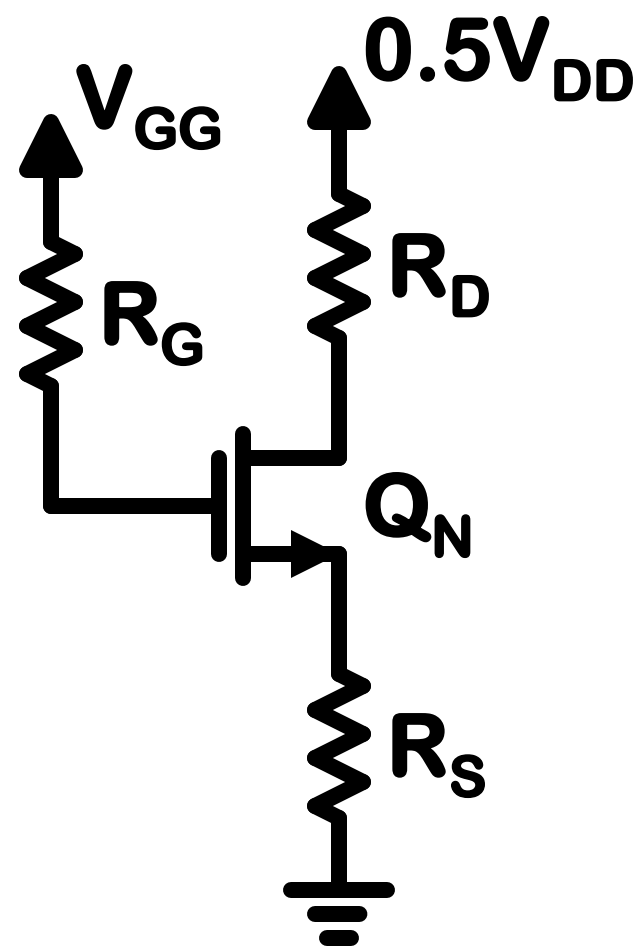
$$v_{GS} = 3.37V$$

$$i_D = (3 - 0.8)/700 = 3.1 \text{ mA}$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} < v_{GS} - V_{tn}, \text{ Yes}$$



1. Triode

2. Enforce (device equation)

$$i_D = 0.002(v_{GS} - 1 - v_{DS}/2)v_{DS}$$

3. Solve

a. Circuit Equations

$$v_{GS} = 4 - 200i_D \text{ or } i_D = (4 - v_{GS})/200$$

$$v_{GS} = v_G - v_S = V_{GG} - 200i_D = 4 - 200i_D$$

$$i_D = (3 - v_{DS})/700$$

$$V_{DD} = 6V$$

$$V_{GG} = 4V$$

$$R_G = 10k\Omega$$

$$R_D = 500\Omega$$

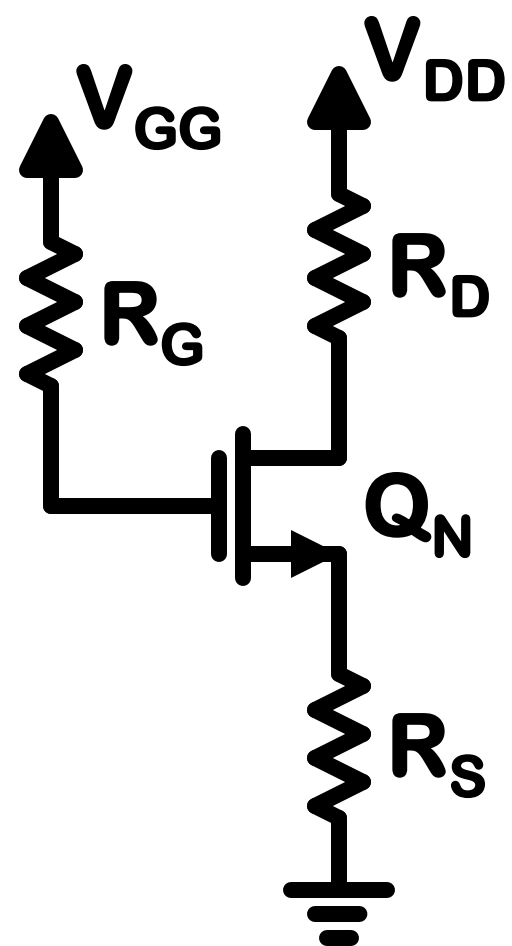
$$R_S = 200\Omega$$

$$R_1 = 200\Omega$$

$$R_2 = 300\Omega$$

$$k_n = 2 \text{ mA/V}^2$$

$$V_{tn} = 1V$$



$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Saturation

2. Enforce (device equation)

$$i_D = 0.001(v_{GS} - V_{tn})^2$$

3. Solve

a. Circuit Equations

$$v_{GS} = 4 - 200i_D \text{ or } i_D = (4 - v_{GS})/200$$

b. Solve

$$(4 - v_{GS})/200 = 0.001(v_{GS} - 1)^2$$

$$20 - 5v_{GS} = v_{GS}^2 - 2v_{GS} + 1$$

$$v_{GS}^2 + 3v_{GS} - 19 = 0$$

$$v_{GS} = (-3 \pm \sqrt{3^2 - 4(-19)})/2 = 3.11V \text{ or } -6.11V \dots \text{choose } 3.11V$$

Choose 3.11V

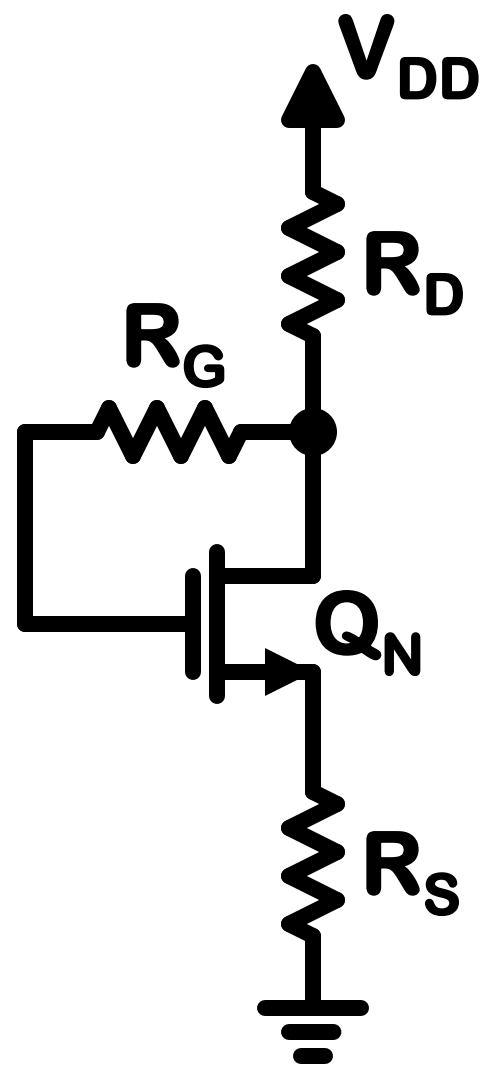
$$i_D = 0.001(3.11 - 1)^2 = 4.45 \text{ mA}$$

$$v_{DS} = 6 - 700i_D = 2.885V$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$



$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Saturation

2. Enforce (device equation)

$$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$$

3. Solve

a. Circuit Equations

$$v_{GS} = v_{DS}$$

$$i_D = (6 - v_{GS})/700$$

b. Solve

$$(6 - v_{GS})/700 = 0.001(v_{GS} - 1)^2$$

$$6 - v_{GS} = .7v_{GS}^2 - 1.4v_{GS} + .7$$

$$.7v_{GS}^2 - 0.4v_{GS} - 5.3 = 0$$

$$v_{GS} = (0.4 \pm \sqrt{0.16 + 4 \cdot .7 \cdot 5.3})/1.4 = 3.05V \text{ or } -2.48V$$

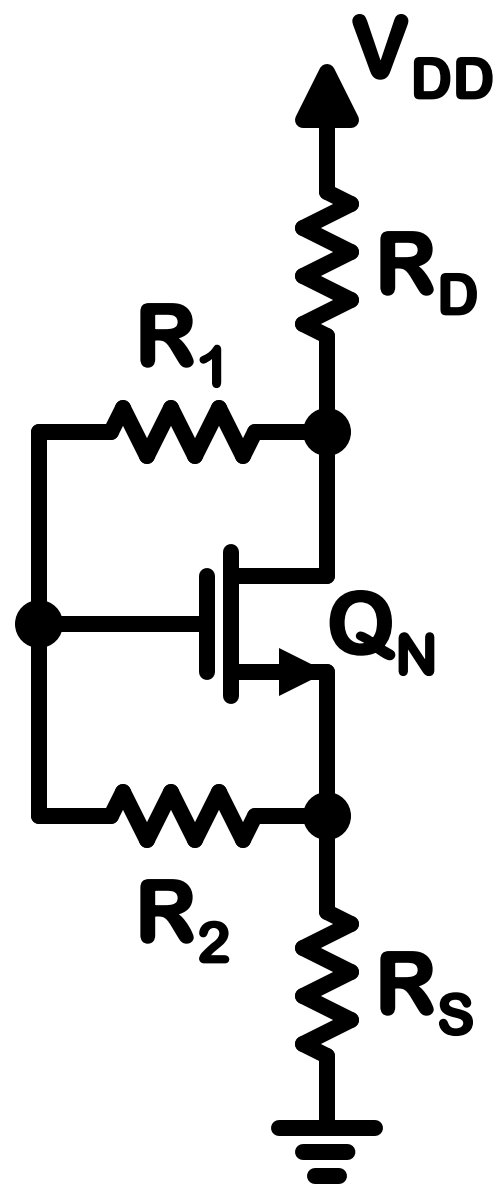
Choose 3.05V

$$i_D = 4.2 \text{ mA}$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$



$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Saturation

2. Enforce (device equation)

$$i_D = (0.5)0.002(v_{GS} - V_{tn})^2$$

3. Solve

a. Circuit Equations

$$v_{GS} = v_{DS}(300/500) = 0.6v_{DS}$$

$$i_D = (6 - v_{DS})/700 - v_{DS}/500$$

b. Solve

$$(6 - 1.67v_{GS})/700 - 1.67v_{GS}/500 = 0.001(v_{GS} - 1)^2$$

$$6 - 4v_{GS} = .7v_{GS}^2 - 1.4v_{GS} + .7$$

$$.7v_{GS}^2 + 2.6v_{GS} - 5.3 = 0$$

$$v_{GS} = (-2.6 \pm \sqrt{2.6^2 + 4 \cdot .7 \cdot 5.3})/1.4 = 1.46V \text{ or } -5.17V$$

Choose 1.46V

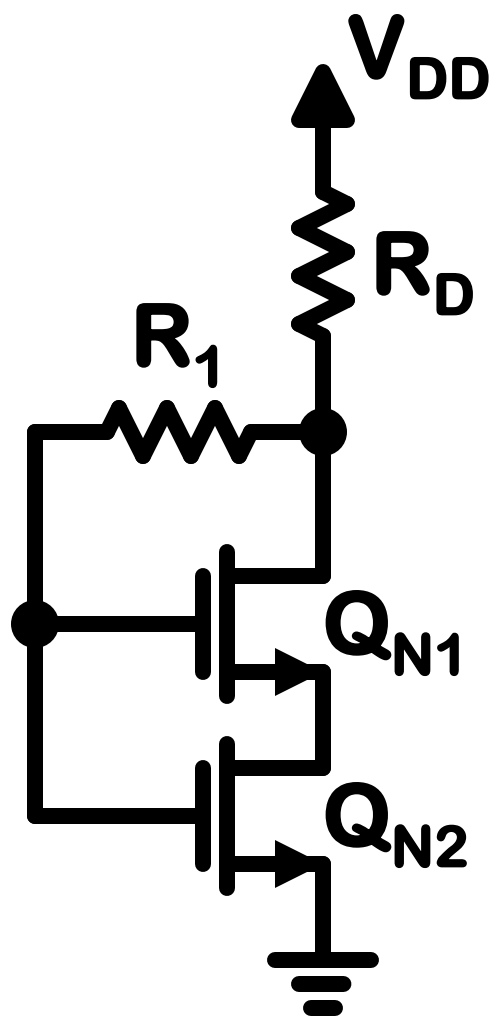
$$v_{DS} = 2.43V$$

$$i_D = 0.25 \text{ mA}$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$



$$\begin{aligned}
 V_{DD} &= 6V \\
 V_{GG} &= 4V \\
 R_G &= 10k\Omega \\
 R_D &= 500\Omega \\
 R_S &= 200\Omega \\
 R_1 &= 200\Omega \\
 R_2 &= 300\Omega \\
 k_n &= 2 \text{ mA/V}^2 \\
 V_{tn} &= 1V
 \end{aligned}$$

1. Saturation, Triode

2. Enforce (device equation)

$$i_{D1} = 0.001(v_{GS1} - V_{tn})^2$$

$$i_{D2} = 0.002(v_{GS2} - V_{tn} - 0.5v_{DS2})v_{DS2}$$

3. Solve

a. Circuit Equations

$$V_{GS1} = V_{DS1}$$

$$V_{GS2} = V_{DS1} + V_{DS2}$$

$$i_D = (6 - (v_{DS1} + v_{DS2}))/500$$

b. Solve

Use Matlab and 3D plot to find intersection

$$v_{GS1} = 3.1V, v_{DS1} = 3.1V$$

$$v_{GS2} = 3.9V, v_{DS2} = 0.8V$$

$$i_D = 4.2mA$$

4. Check

$$v_{GS} - V_{tn} > 0, \text{ Yes}$$

$$v_{DS} > v_{GS} - V_{tn}, \text{ Yes}$$

